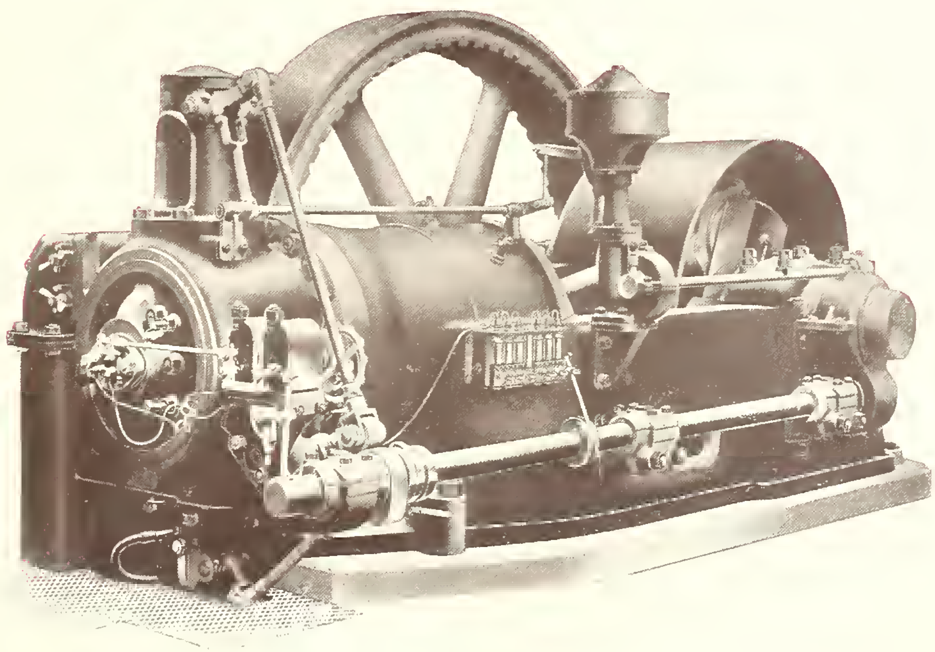
HORIZONTAL GAS ENGINES

SMALL *and* MEDIUM SIZE

Horizontal Gas Engines

SMALL AND MEDIUM SIZE



VACUUM OIL COMPANY

Rochester, N. Y., U. S. A.

FIRST PRINTING

HORIZONTAL GAS ENGINES

SMALL AND MEDIUM SIZE

Classification; Field of Service; Construction; Principle of Operation; Cooling; Gas; Methods of Lubrication; Oil; Deposits

CLASSIFICATION

Small and medium size horizontal gas engines may be classified as follows:

Size	*No. of Cylinders*	*H. P. per Cylinder*	*Revolutions per minute*
Small size	One cylinder	1— 50	500—190
Medium size (without water-cooled pistons)	Usually one; Sometimes two	50—150	190—140
Medium size (with water-cooled pistons)	Usually one; Sometimes two	80—250	180—130

When a gas engine develops *more than* 250 *H. P. per cylinder* it is classed as a *large* gas engine.

FIELD OF SERVICE

Small and medium size horizontal gas engines have come much in prominence in various parts of the world during the last decade as economical power producers, particularly in districts where there is no large central power supply.

They are also extensively used as standby power units—that is, power units to fall back on when the regular equipment is out of service—for example, in plants operated by water power where, in the winter time, the water supply is curtailed so that extra power is needed.

They are also employed in small electrical power stations for driving generators; also as main or auxiliary power producers in small factories, engineering works, sawmills, wood-working shops, mines, quarries, refrigerating plants, etc.

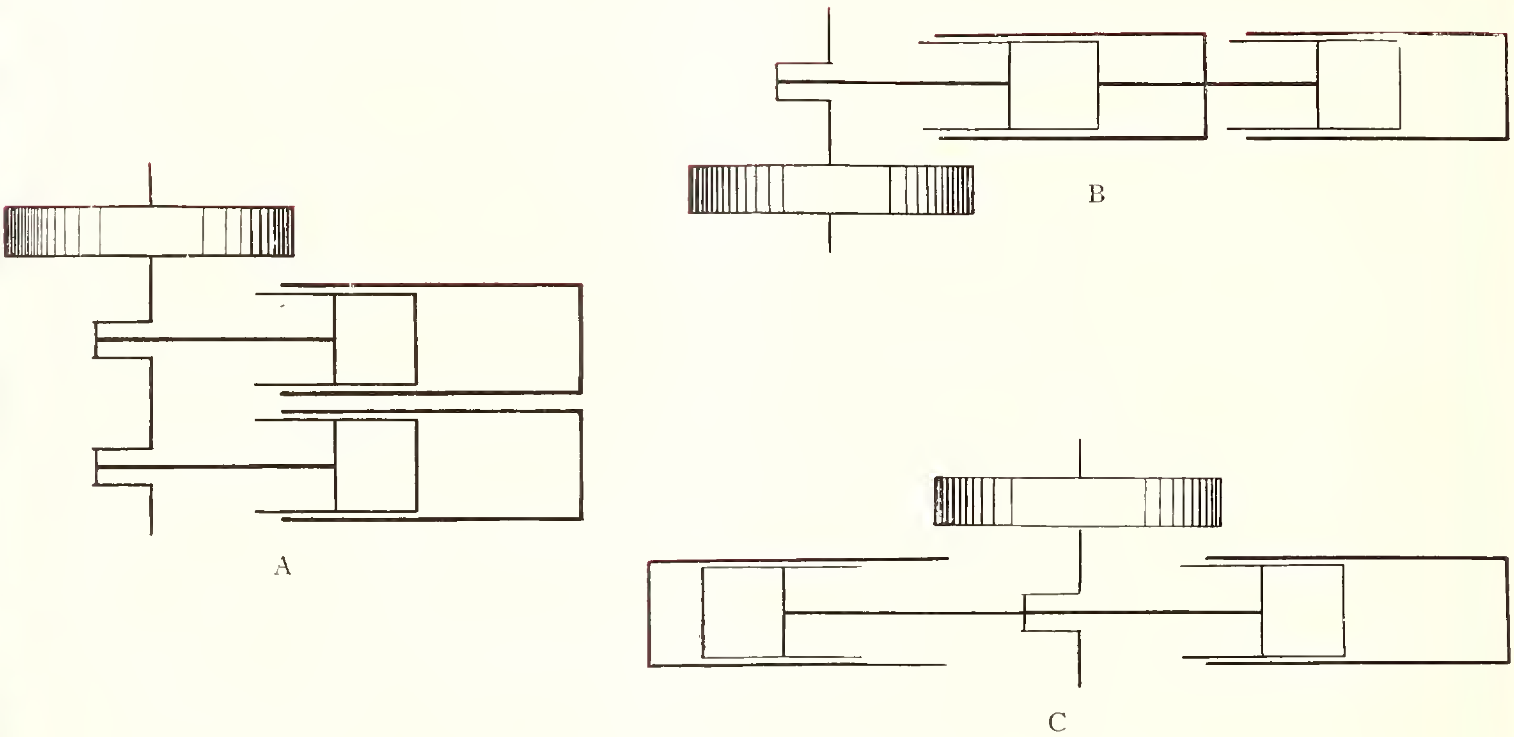


Fig. 1. Cylinder Arrangement

CONSTRUCTION

Small horizontal gas engines have only one cylinder.

Medium size horizontal gas engines usually are made with one cylinder, but sometimes with two.

There are three types of two-cylinder arrangement, as shown in Fig. 1.

Side by side (A), Twin System;

One behind the other (B), Tandem System;

Opposed positions (C), Opposed System.

Figs. 3, 6 and 7 show sectional views of typical small and medium size horizontal gas engines.

In the cylinder (A) is a close-fitting trunk piston (B)—a long open-ended hollow piston, fitted with piston rings (B1) preferably held in position in their grooves and prevented from revolving by means of small pins or pegs (B2, Fig. 6) placed in different positions for the different rings, so that the joints of the rings cannot work in line and allow the gases to blow past them.

To the piston (B) one end of the connecting rod (C) is pivoted on the gudgeon, or wrist pin (B6), which is firmly fixed in the body of the piston (B).

The other end of the connecting rod engages the crank pin (E).

The horizontal, straight-line movement of the piston (B) is thus transformed, by the pendulum motion of the connecting rod (C), into rotary motion of the crank shaft (F).

On the main shaft (F) which is supported by main bearings (F2) is fixed the flywheel (F1).

From the main shaft (F) is driven, by gear transmission, the cam or timing shaft (G) upon which are fixed the cams (G1) for operating the inlet valve (H) and the exhaust valve (H1).

The cam shaft also operates the magneto (not shown) which, at the proper instant, produces a spark at the spark plug (J1) in the combustion chamber of the cylinder (A). The heavy flywheel (F1), when turning at full speed, gives the engine a regular and uniform motion.

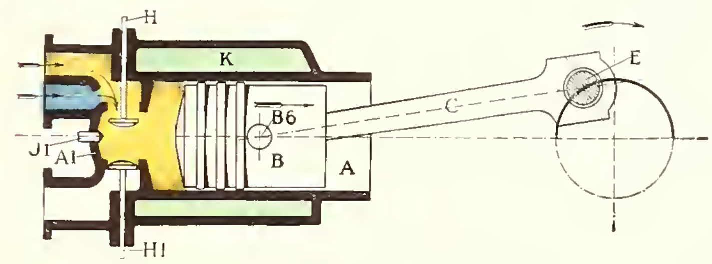
Power is distributed from the gas engine to the shafting by belt or rope transmission from the flywheel, by geared drive from the main shaft, or an electric generator is mounted on an extension of the main shaft.

PRINCIPLE OF OPERATION

Small gas engines are started by throwing out the engaging clutch, if the engine transmits its power by rope, belt or gearing, and turning the flywheel by hand until the engine operates automatically.

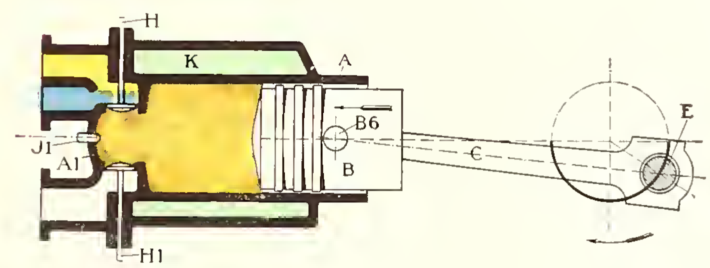
Medium size gas engines are usually started by the use of compressed air from tanks or storage bottles. When compressed air is not used, the same procedure is followed as for small gas engines.

All small and medium size gas engines operated on the four-stroke cycle principle. A four-stroke cycle engine completes one cycle of events in four strokes of the piston, *i. e.*, the suction, compression, power and exhaust strokes.



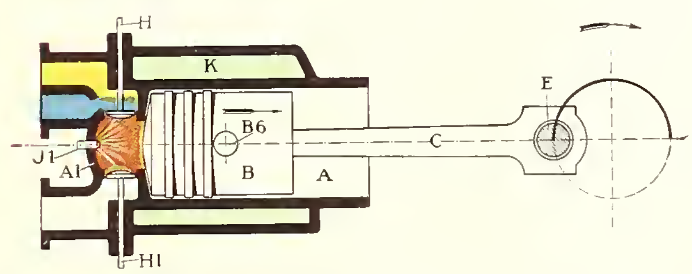
First or
Suction Stroke

Gas and air, constituting the fuel charge, are sucked into the cylinder (A) through the inlet valve (H) as the piston (B) moves outwards, *away from* the cylinder head (A1). The exhaust valve (H1) is closed.



Second or
Compression Stroke

The piston (B) moving inward, *towards* the cylinder head (A1), compresses the fuel charge. Both inlet and exhaust valves (H) and (H1), respectively, are closed.



Third or
Power Stroke

Ignition by the spark (J1) of the compressed fuel charge produces explosion and expansion of the gases, forcing the piston outwards, *away from* the cylinder head (A1) during the power stroke. Both inlet and exhaust valves (H) and (H1), respectively, are closed.

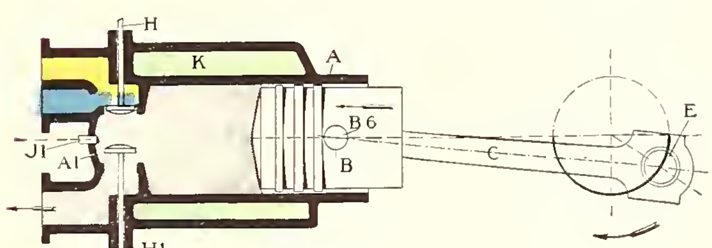


*FIG. 2

Fourth or
Exhaust Stroke

The piston (B), moving inward, *towards* the cylinder head (A1), drives the burned gases out thru exhaust valve (H1). Inlet valve (H) is closed.

Thus the four strokes of the piston, *i. e.*, one power stroke followed by three idle strokes, complete the cycle of events; hence the expression four-stroke cycle

In a one-cylinder gas engine, the flywheel thus makes two revolutions for every power stroke. In a two-cylinder engine, with alternate explosions in the two cylinders, one power stroke occurs for every revolution of the flywheel.

*In this and all following illustrations red indicates oil, blue indicates air, green indicates water and yellow indicates gas.

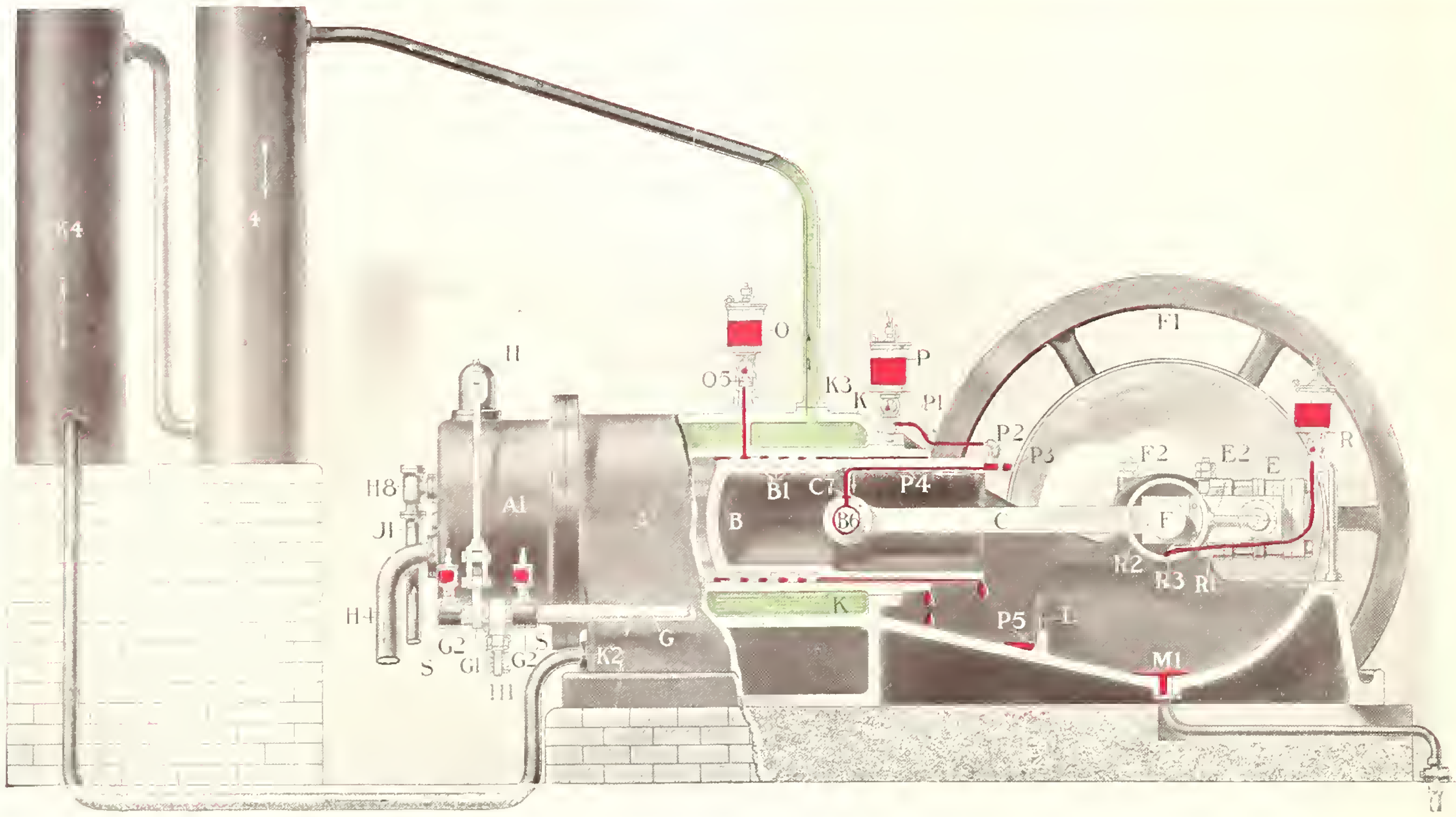


Fig. 3. Improved System of Lubrication Showing Details of Cooling System

COOLING

In small and medium size gas engines a temperature of from 2000° F. to 2600° F. is developed at the instant of explosion of the gases in the cylinder. As the gases expand the temperature decreases. The average temperature of the expanding gases is about 1400° F. during the power stroke.

Cooling of all parts of the engine that come in contact with the hot gases is necessary. Without adequate cooling, unequal expansion and distortion of the overheated parts, excessive wear and piston seizure would occur.

The *cylinders* of both small and medium size horizontal gas engines are always water-cooled. Where the power per cylinder exceeds 150 H. P. the heat development is so great that the *piston* must also be water-cooled. Indeed, many builders employ water-cooled pistons in engines ranging in size from 80 H. P. to 150 H. P. per cylinder. Where the rated power is less than 80 H. P. per cylinder, the pistons are never water-cooled.

Thermo-Syphon Cooling System (Fig. 3)

In this system, slow, constant circulation of the cooling water is maintained by virtue of the difference in the density between the hot and cool water in the cooling system. The colder water always sinks to the lowest position in such a system. Upon being heated in the cylinder jacket it rises and passes to the top of the cooling tank.

The cooler water in the tank is forced into circulation by this displacement and sinks down into the bottom of the water jacket, whence, after becoming heated, it again rises to the cooling tanks.

This system is generally employed in small gas engines and sometimes for the smaller medium size gas engines.

The cooling water enters the water jacket (K), Figs. 3, 6 and 7, at the bottom through pipe (K 2) and circulates around the cylinder walls (A), which assume a resultant temperature of 200° to 300° F. The water leaves the jacket through the outlet (K3) and, being hot, rises through pipe (K3) and enters the cooling tank or tanks (K4).

These are placed at a level higher than that of the engine so that the water after cooling flows back by gravity (the Thermo-Syphon System) to the engine, reentering the cylinder jacket by pipe (K2).

In the inlet and outlet pipes (K2) and (K3), respectively, should be fitted thermometers for registering the temperature of the cooling water.

The temperature of the cooling water at the outlet (K3) should be not less than 100° F., and not more than 140° F.—120° F. being preferable.

If the temperature of the outlet water from the water jacket is much above 140° F., the cooling of the cylinder walls becomes deficient. The temperature rises, the oil film is thinned out, losing its sealing power, and the exploding gases blow past the piston.

If the temperature of the outlet water is much below 100° F., the cooling of the cylinder walls is over-efficient. The oil film becomes sluggish, the oil spreads with difficulty and a great deal of power is lost in overcoming the oil drag on the piston.

A temperature of about 120° F. is therefore preferable in order to insure good piston seal and a free sliding motion of the piston—in short, the highest degree of operating efficiency.

The larger the engine the more cooling required.

This would ordinarily involve the use of larger cooling tanks.

Most manufacturers of medium size gas engines, however, instead of employing large, bulky cooling tanks, employ relatively small cooling tanks, but increase the cooling capacity by rapid circulation of the cooling water. This rapid circulation is usually effected by means of a circulating pump installed somewhere in the circuit.

Pump circulation is more positive in operation than the Thermo-Syphon System, but the latter is simpler and less expensive.

For cooling purposes, city water is sometimes employed, being connected directly to the water jacket opening. In such cases the used water is allowed to run to waste.

The cooling water must be clean, for, if impurities settle in the water jacket (K), the cooling of the cylinder walls (A) becomes defective, the temperature rises and preignition, caused by incandescent deposits inside the combustion chamber, is likely to occur. The lubricating oil film between the piston (B), piston rings (B1) and cylinder walls (A) is thinned out, losing its sealing power. The exploding gases blow past the piston rings. Oil is burned and charred and its lubricating value destroyed. Heavy wear and loss of power are the inevitable results.

GAS

Small and medium size gas engines are operated by one of the following kinds of gas—natural gas, illuminating or town gas, suction producer gas or pressure producer gas. Of these, the last three are artificially made; their heat values differ considerably.

The more the given mixture of gas and air is compressed on the compression stroke, the greater will be the power developed when the mixture is ignited.

When using rich, highly inflammable gas, such as natural gas, the compression must be proportionately low, otherwise preignition will occur, due to the heat developed by compression.

With weak, less inflammable gas, such as producer gases, the compression pressure at the end of the compression stroke can be made much higher.

This is shown in the following table, which gives average comparative heat value of gases in British thermal units (B. T. U.) and operating compression pressure in lbs. per square inch.

	Heat Value B. T. U.	Compression Pressures Lbs. per sq. in.
Natural Gas	1,000	100
Illuminating Gas	600	120
Producer Gas (suction or pressure)	140	160

Natural Gas

Natural gas is found in the oil districts of the United States and Canada. It exists in the earth in pockets and is reached by wells which are drilled to the pockets. It is dry in its natural state, with a degree of purity that makes cleaning unnecessary.

Natural gas is highly inflammable. Freedom from impurities, low cost and efficiency make it the ideal fuel for gas engines where it can be obtained.

Illuminating or Town Gas

Illuminating gas is used for small gas engines only, up to a maximum of 50 H.P., which is rarely exceeded. Gas engines of larger size use producer gas because it is cheaper than illuminating or town gas.

Illuminating gas is made from bituminous coal by dry distillation. During this process an appreciable quantity of tar is carred over with the gas and is extracted. The gas ultimately produced is dry and free from impurities, and is, therefore, an excellent fuel.

Coke is the product remaining in the retorts. It is free from volatile and tarry matters but contains the whole of the ash originally present in the coal.

Suction Producer Gas (Fig. 4)

Suction producer gas is usually made from anthracite coal, coke of various kinds, lignite, wood refuse, etc.

The engine draws from the gas producer by suction the gas required for its operation, hence the name *suction* producer gas.

Suction producer gas plants are used for installations where the power of a plant, comprising one or more engines, does not exceed 500 H. P. In such plants, suction producer gas is used in preference to illuminating gas on account of the lower cost.

The suction producer gas plant, however, is small compared with the large illuminating gas works, and the method of cleaning the gas is less efficient. The gas usually, therefore, contains impurities. As this is an important point, it may be useful to illustrate the construction and operation of a typical suction producer gas plant (Fig. 4).

Air is drawn through the generator (1) filled with fuel (3), the lower portion of which is incandescent over the grates (2).

Water passes through the pipe (4) into the evaporating pan (5), which is circular in form. The heat of the burning fuel (3) in the generator (1) produces steam in the evaporating pan (5); the steam passes down through pipe (6) and, together with the air, enters the generator (1) from below the grate (2), rising through the fuel in the generator (1) and producing gas.

The gas travels through pipes (7) and (8); some dusty impurities drop into the water trap (9). The warm gas then enters the bottom of the scrubber (10), which is usually filled with clean coke or charcoal (11). These, being porous and bulky, absorb impurities easily, yet provide plenty of air space for the circulation of the warm gas.

A water spray at the top of the scrubber (10) playing on the coke or charcoal (11) cools and purifies the rising gas. Through the pipe (12) the gas goes to the tar separator (13), in which the tar is deposited by precipitation.

The tar separator is not necessary when the gas is produced from coke which contains practically no tar.

Occasionally a sawdust filter is installed after the tar separator to free the gas from excessive moisture developed when moist fuel, such as wood refuse, is used.

In order to insure regular flow of gas from the producer, a gas receiver (16) is installed. The gas engine sucks in the gas as required.

A hand-operated blower (1A) is used for furnishing an air blast when starting the generator.

When blowing up the fire, the cock (19) directs the gas through the test pipe (18) to the atmosphere until the quality of the gas is correct. The cock (19) is then turned to the position shown in the drawing, allowing the gas to pass to the scrubber.

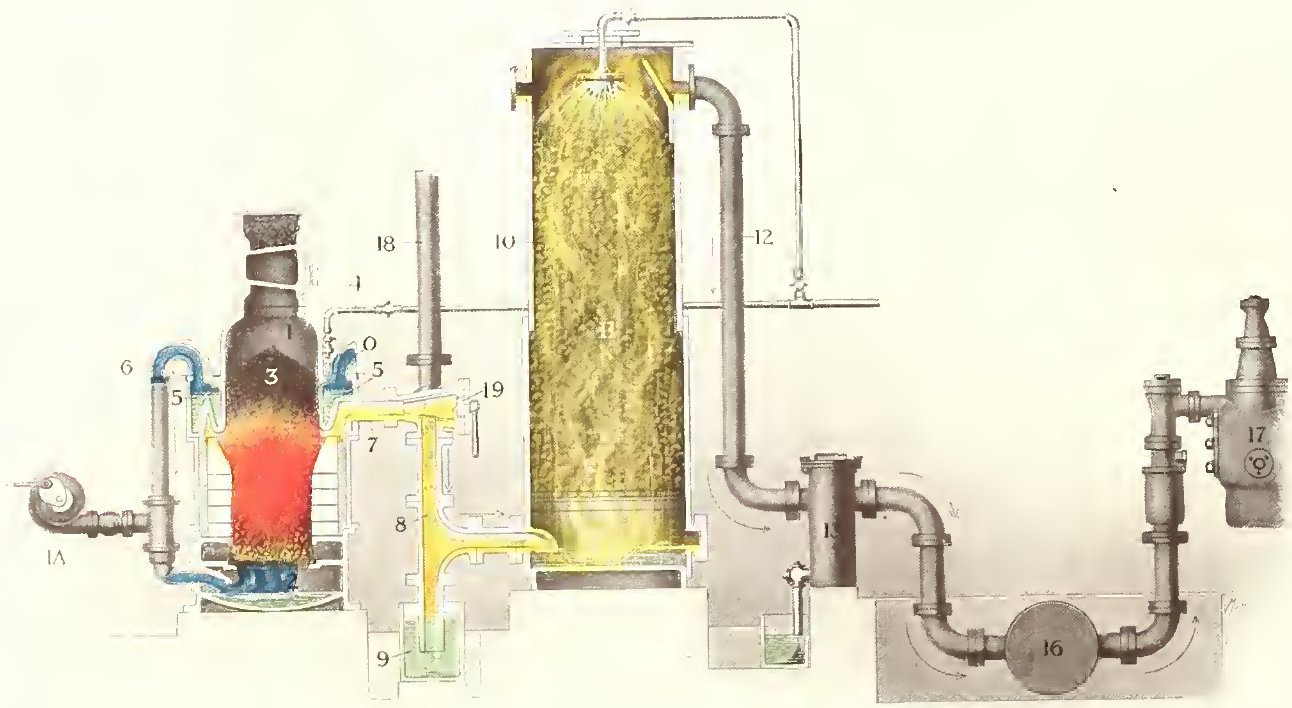


Fig. 4. Suction Producer Gas Plant

Pressure Producer Gas (Fig. 5)

Pressure producer gas is made from a variety of fuels, such as bituminous coal, lignite, coke, anthracite, charcoal, sawdust, wood refuse, etc. The gas is produced under slight pressure, hence the name *pressure* producer gas.

Pressure producer gas plants are sometimes used for installations as small in size as 200 H.P., but the installations usually range from 400 H.P. to 2,000 H.P. in plants where medium size gas engines are employed. In these larger installations, comprising a number of units of medium size, pressure producer gas plants are used because they give a more uniform and reliable gas supply; also, with them, a greater variety of fuels can be used.

Where bituminous coal is used, rich in tarry matters, the cleaning plant for the gas must be more elaborate and efficient, and, therefore, more costly than in the case of suction producer gas plants.

Where the pressure producer gas plant supplies gas for an installation of 2,000 H. P. or more, a by-product plant for the treatment of the tar is frequently installed. Sulphate of ammonia and other valuable by-products are obtained from the tar, and this helps to lower the operating cost.

Fig. 5 illustrates a typical pressure producer gas plant.

The generator (1) is filled with fuel (3). Steam is generated under slight pressure in the boiler (1A), flows through the pipe (6) and injects air coming from the air heater (1B) through pipe (5) into the bottom (2) of the generator (1).

Steam and air rise through the incandescent fuel in the generator, gas is produced and leaves the generator (1) through the pipe (7). The warm gas passes through "down" pipe (8) and enters the scrubber (10) filled with clean coke or charcoal (11).

Cold water enters the scrubber at the top and is sprayed over the coke, cooling and purifying the rising gas. Through pipe (12) the cool gas is conducted to the tar separator (13).

Occasionally a revolving tar separator is employed, which frees the gas from the greater quantity of liquid tar by centrifugal force.

The gas now passes the drying and cleaning filter (14) filled with sawdust, and after passing another tar separator (15)—sometimes used when the proportion of tar is excessive—enters the gas receiver (16) which, in large installations, is similar to the gas holders in illuminating gas works.

From the receiver (16) the gas is delivered to the gas engine or engines, as required, under a slight and constant pressure.

It is to be noted that producer gas is always moist and contains more or less impurities, such as soot, very fine dust, ash—and tar, notwithstanding the precautions taken to clean it before it reaches the engine.

Where lignite is used as fuel, it is not necessary to introduce steam into the generator, the lignite containing sufficient moisture. Air only is blown into the generator by means of a centrifugal blower.

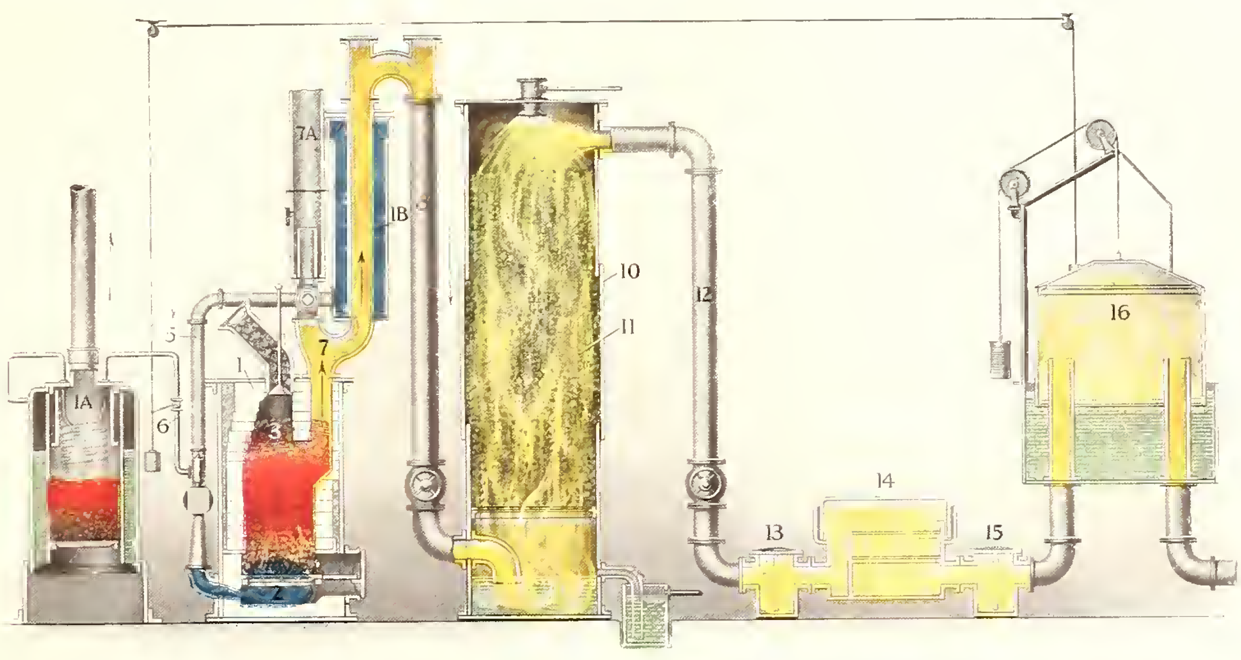


FIG. 5. PRESSURE PRODUCER GAS PLANT

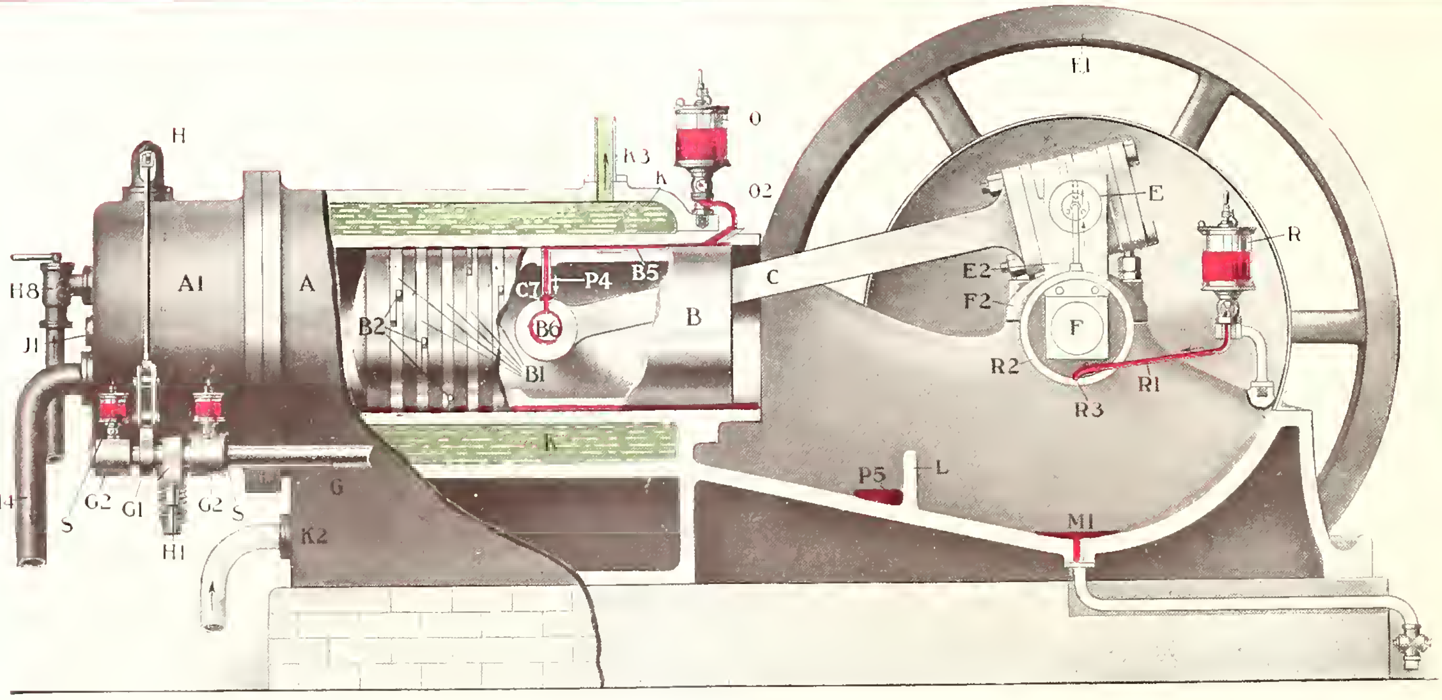


FIG. 6. OLD SYSTEM OF LUBRICATION

METHODS OF LUBRICATION

The lubrication of small and medium size gas engines may be classified under three main systems, namely:

The Old System (Fig. 6); the Improved System (Fig. 3), and the Positive System (Fig. 7).

Old System of Lubrication (Fig. 6)

Main Bearings (F2)—These are generally ring oiled bearings (Fig. 8). Oil rings (R4) are suspended from the shaft (F) within the bearing housing (F2). When the shaft revolves, the oil rings automatically carry oil from the reservoir below to the top of the shaft, where it spreads and lubricates the bearing surfaces, afterwards returning to the oil reservoir.

Crank Pin Bearing (E)—This bearing is lubricated by means of a hollow ring (R2) fastened to the crank web (E2), the oil being fed from a sight feed drop oiler (R) through the pipe (R1) into the ring (R2) at the point (R3). By centrifugal force the oil is thrown into the drilled hole in the center of the crank pin (E) and through a radial hole reaches the bearing surfaces.

Piston (B)—The oil is fed from a sight feed drop oiler (O) into the oil pipe (O2), and through a hole in the cylinder wall reaches the piston. The oil spreads over the surface of the piston, furnishing lubrication and a piston seal; it also tends to wash away impurities which the oily surfaces collect.

Gudgeon or Wrist Pin (B6)—On the upper surfaces of the piston (B) a groove (B5) is provided, in which some of the oil fed from the lubricator (O) collects. The oil drops through the tube (P4) and the oil hole (C7) to the bearing surface of the wrist pin (B6). (See *Wrist Pin* under *Oil*).

Cam Shaft (G)—The cam shaft (G) is supported by bearings (G2) which are preferably ring oiled, but sometimes are plain bearings lubricated by small sight feed drop oilers (S).

Valve Spindles and Cams—The valve spindles (not shown) of the inlet and exhaust valves (H) and (H1), respectively, as well as the cams (G1), are sparingly oiled by hand.

Improved System of Lubrication (Fig. 3)

The lubrication of main bearings, crank pin bearings, cam shaft bearings, valve spindles and cams is effected in the same manner as described under the Old System of Lubrication (Fig. 6). The improvement lies in the provision made for independent oiling of the piston and gudgeon or wrist pin.

Piston (B)—The sight feed drop oiler (O) supplies oil to the piston and piston rings only. The oiler (O) should preferably be provided with a ball check valve (O5), to prevent "blow back" of escaping gases through the vertical pipe into the sight feed.

Gudgeon or Wrist Pin (B6)—The sight feed drop oiler (P) feeds the oil through the oil tube (P1) to the distributor (P2). The oil is wiped off by the oil catcher (P3), from which it is led through the tube (P4) and drops through the

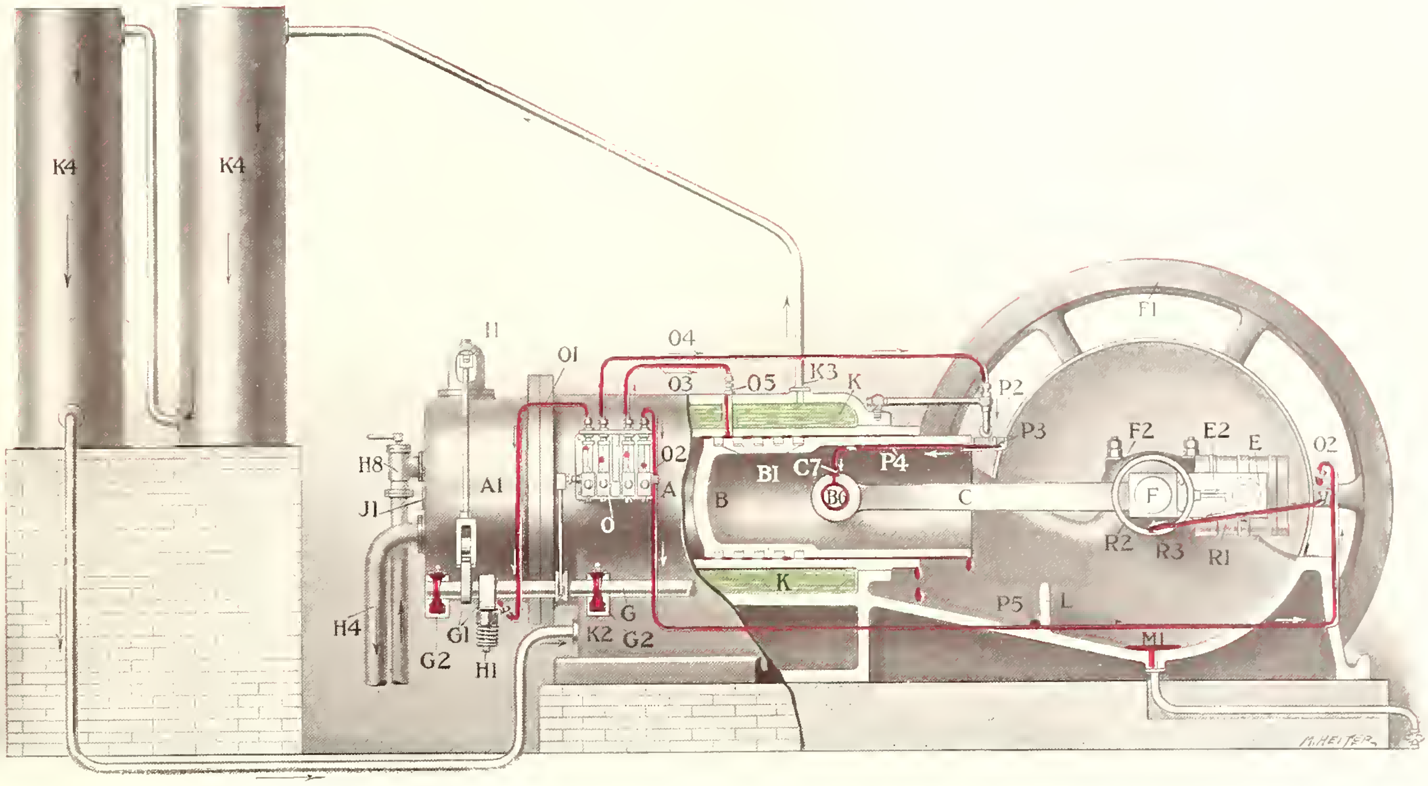


Fig. 7. Positive System of Lubrication

oil hole (C7) to the wrist pin bearing surfaces. By this method the oil feed to the wrist pin can be adjusted to the exact amount required for correct and economical lubrication.

The Positive System of Lubrication (Fig. 7)

By this system positive and uniform lubrication is supplied to piston, crank pin, wrist pin and exhaust valve spindles by means of a mechanically operated lubricator (O), thus providing great economy and certainty of operation.

The various feeds of the lubricator (O), once adjusted, require no further attention. One filling of the mechanically operated lubricator lasts a long time, whereas sight feed oilers not only must be frequently filled and adjusted, but demand further attention as starting and stopping of the oil feeds is required.

The lubricator (O) is operated from the cam shaft (G). A cam actuates an oscillating lever which gives motion to the internal mechanism in the oiler so that pump plungers automatically pump oil through all the feed pipes.

The mechanically operated lubricator generally has four oil feeds, *i. e.*, to the piston, crank pin, wrist pin and exhaust valve spindle.

In order to insure that the oil pipes are always full, they should be provided at the extreme ends with spring loaded check valves (O5).

When the lubricator is working, the pressure on the oil in the oil pipes forces open the check valves and the oil is delivered to the respective points.

When the engine is stopped and the lubricator ceases to operate, the check valves prevent the oil from running out of the pipes. The pipes are thus kept constantly full of oil and instant lubrication is assured whenever the engine and lubricator start to operate.

Crank Pin Bearing (E)—The oil pipe (O2) from the mechanically operated lubricator (O) delivers the oil, automatically and uniformly, through the pipe (R1) into the ring (R2) and into the crank pin bearing, as previously described.

Piston (B)—The oil pipe (O3) from the mechanically operated lubricator (O) feeds the oil under pressure, at the right moment, and to the ideal place, which is between the first and second piston rings (B1), when the piston (B) is at its most outward position. This enables the piston to carry the oil well into the cylinder; in fact, the piston acts as the oil distributor.

Gudgeon or Wrist Pin (B6)—The oil pipe (O4) from the mechanically operated lubricator (O) delivers the oil through the check valve to the distributor (P2). The oil catcher (P3) on the end of the piston (B) collects the oil and conveys it by the tube (P4) to the wrist pin, as previously described under *Improved System.*

Main Bearings (F2)—In small gas engines, these are nearly always ring oiled bearings (Fig. 8). Occasionally, in medium size gas engines, the main bearings are fed by gravity from an elevated oil tank, the oil after leaving the bearings being drained away to a receiving tank, from which an oil pump delivers it back into the elevated tank.

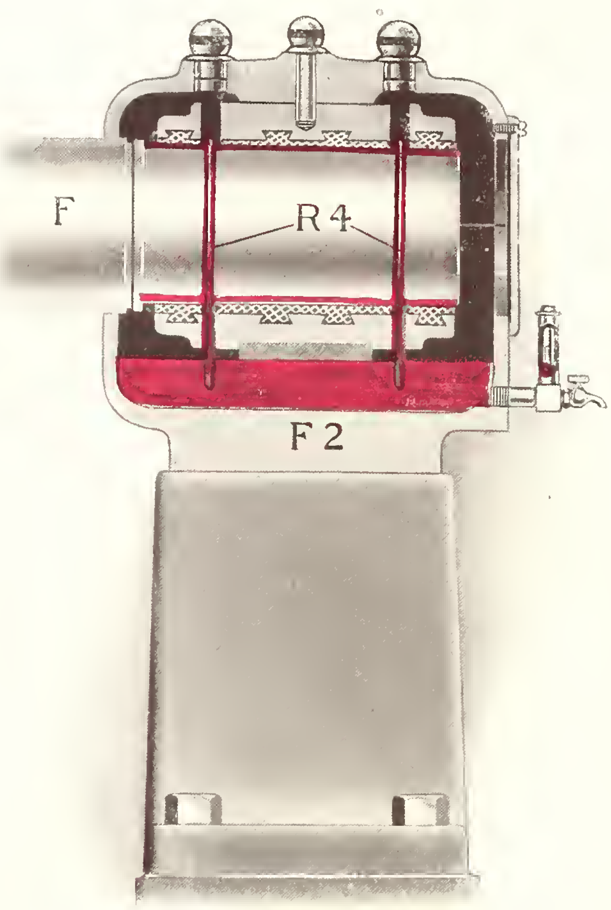


Fig. 8. Ring Oiled Bearing

Cams and Valve Spindles—The cams and inlet valve spindles are usually oiled by hand, but in the larger gas engines it becomes necessary to lubricate the spindle of the exhaust valve (H1) by means of a uniform and very sparing supply of oil through the oil pipe (O1) from the mechanically operated lubricator (O).

Irregular or excessive oil feed produces carbon deposits which cause the exhaust valve spindle to bind or stick.

With an excessive oil feed the *excess* oil burns and *carbonizes.*

With *too sparing* a supply of oil, too little lubrication is provided. The spindle becomes overheated and *carbonizes the oil* fed to it.

In either case the exhaust valve spindle is inclined to bind or stick.

OIL

The lubricating oil used on small or medium size horizontal gas engines has a very important bearing on their operation.

High-grade oils especially suited to gas engine requirements and properly applied will decrease frictional losses to a minimum. The frictional losses of a small or medium size gas engine amount to from 12% to 25% of its rated horsepower *regardless of the actual load on the engine.*

By the use of high-grade oils as compared with ordinary oils, the total amount of gas consumed by the engine may be reduced 5% to 10%, the engine doing the same amount of useful work; the cost of maintenance and repairs is much reduced; there is less possibility of breakdown, and the engine will have a longer life.

If an oil of *too heavy body* is used for cylinder lubrication, it does not easily spread over the piston surface; in addition, the friction is high, owing to the heavy oil drag on the piston. Impurities in the gas or air cling to the heavy oil and bake into crustlike deposits.

If an oil of *too light body* is used, it will break down under the influence of the high temperature in the cylinder, losing its sealing power and causing excessive wear of the piston, piston rings and cylinder walls. Deposits are formed containing a large percentage of iron and iron oxides, due to the wear of the cast-iron piston, piston rings and cylinder.

The ring oiled *main bearings* (F2) generally give little trouble and should run fairly cool. If the bearing temperature is high, it is due to the use of an unsuitable or a poor quality oil, or to mechanical defects in the main bearings, or poor alignment of the main shaft.

When using an ordinary oil, it must be changed as often as every four weeks, whereas high-grade oil may last indefinitely with small loss.

When ordinary oil is used and the working temperatures are high, the engineers frequently add oil to the main bearings every day, which, however, does not cool them, and, besides being wasteful, means an unsightly engine room, as the oil will overflow from the bearings.

The *crank pin* (E) is a very important part of the engine as it transmits the power from the

piston to the main shaft. Special attention must be given that the proper quality and quantity of oil are used.

Ordinary or improperly selected oils cause high temperature and large oil consumption. There is also the danger of excessive wear, which frequently takes place, resulting in pounding.

Good quality oils can be sparingly used; they furnish adequate lubrication and minimize or prevent wear.

Occasionally a heavy-bodied oil is required for lubricating the crank pin of medium size horizontal gas engines owing to the heavy crank pin bearing pressures. As this oil may be too heavy in body for the cylinder lubrication, sometimes two different oils are used, although such cases are the exception.

The *piston* (B) of the gas engine is the most vital part from a lubricating standpoint. In case of impure or unsuitable oils or overfeeding, deposits develop on the piston head and behind the piston rings (B1), and a portion will appear on the piston in the form of a black, oily coating.

These deposits soon cause the piston rings to cement in their grooves. The gases blow past the piston. Excessive wear takes place on the piston rings (B1) and on the cylinder walls (A) with the possible result, in extreme cases, of breaking the rings or stopping the engine altogether.

With a high quality oil, less is required than with an ordinary oil, and the formation of carbon deposit is reduced to a minimum.

It should, therefore, be emphasized that to secure the best results—*the gas should be as clean as possible; specially selected high-grade oils should be used; the quantity of the oil reduced to the exact amount required, and the oil applied in the best possible manner.*

The *gudgeon or wrist pin* (B6) requires particular care in lubrication as it is located in the interior of the heated hollow trunk piston (B) where it is subjected to high temperature.

The pressures on the wrist pin are high and, as the pendulum motion of the connecting rod is slight, the oil spreads with difficulty over the bearing surfaces. Consequently, the lasting and lubricating properties of the oil used are of the highest importance.

It is quite obvious that an *unsuitable* oil will cause heavy wear of this bearing and particularly with the old system of lubrication (Fig. 6), where the oil from the piston groove delivered to the wrist pin is contaminated with carbonized oil, etc. By this system it is necessary to feed an excessive amount of oil to the piston in order that the wrist pin may receive sufficient oil through oil tube (P4). Surplus feed to the piston always results in carbon deposits and waste.

In the better systems of lubrication (Figs. 3 and 7) the wrist pin is oiled by a separate oil feed and, therefore, the requisite quantity of the proper grade of high quality oil can be supplied.

The blackened waste oil coming from the piston and wrist pin should be arrested by a division plate (L) (Figs. 3, 6 and 7) and drained away at (P5), so that it will not run into the crank pit (M) and contaminate the waste oil from the crank pin.

DEPOSITS

Deposits are generally, not always correctly, termed carbon deposits.

Deposits may arise from one or several of the following causes: dust or dirt in the intake air; impurities in the gas; soot from incomplete combustion; overfeeding of oil; the use of an unsuitable oil.

The formation of deposits under certain conditions leads to preignition and back-firing.

Intake air is usually not filtered, even when the engines are placed in dirty surroundings. Impure intake air is therefore a frequent cause of deposits in gas engines, regardless of the kind of gas used.

In such cases a chemical examination will prove the presence of sand, brick dust, lime dust, etc. The deposit will also contain oil and partly decomposed oil, due to the action of the impurities on the oil under high temperature conditions. Furthermore, there will be present a percentage of iron and iron oxides, due to the wear of the piston rings and cylinder.

When *natural gas* or *illuminating gas* is in use, deposits, owing to the purity of the gas, can develop only in case of incomplete combustion, which may be due to poor ignition or improperly timed inlet and exhaust valves.

Where *producer gas* is in use, deposits may be caused by impurities in the gas, such as ash, fine coke dust, free soot, or tar passing into the engine. All fuels contain ash, and a regular feeding of fuel through the generator and removal of clinker from the grates are necessary.

In the generator the ash is constantly seeking its way from the fire down through the grate, and, if the grate is not covered with a sufficient layer of fuel, fine ash is likely to be carried up and away with the gas. Regular firing is therefore important, as it prevents the layer of fuel from getting too low.

Where coke is used, there is no tar, but coke dust may be carried over in such fine form that neither the water trap (9), scrubber (10) nor filter (14) (Figs. 4 and 5) will remove it.

Where gas is produced from anthracite coal, tar and soot may both be carried over, although anthracite contains only a small percentage of tar.

Where gas is produced from lignite, which contains more tar and soot, the danger of forming deposits inside the engine is more pronounced.

Lignite also contains a small percentage of sulphur; this in many cases will cause a blackening of the piston surface which, however, in itself need not cause any trouble.

Where gas is produced from bituminous coal which contains a large percentage of tar, there is a greatly increased likelihood of the gas carrying soot and tar into the engine.

Wet gas, such as the producer gases, forms a paste with the impurities in the air or gas, providing a base for the ready formation of deposits.

The impurities collect in the mixing and inlet valves and passages, and on the internal surfaces of the engine exposed to the gas, adhering to and contaminating the oil film on the piston, piston rings and cylinder walls.

If, upon examining the inlet valve, tar and soot be found, this proves that the trouble is due to impurities in the gas, as it is impossible for the lubricating oil to reach the inlet valve.

Overfeeding of Oil: Overfeeding, even when using a good oil, will produce carbon deposits. The surplus oil passes to the back of the piston —the side nearest the spark—where it is burned and charred. The formation of deposits is aggravated by the presence of impurities in the gas, or by incomplete combustion, as the impurities adhere to and bake together with the surplus oil.

Unsuitable Oil: Unsuitable oil must be used in excess to provide lubrication. The surplus oil passes the piston, burns and chars freely, and readily combines with impurities in the gas or products of incomplete combustion, forming hard, crustlike deposits.

Preignition and Backfiring: Where deposits develop inside the combustion chamber, particularly if the water cooling is inefficient, they often become incandescent and the fuel charge is fired before ignition would ordinarily take place. This is called preignition and causes abnormally heavy strains on the piston, wrist pin and crank pin.

Preignition may also occur when engines designed for suction gas use illuminating gas, as the latter is richer and will ignite at a lower compression pressure than producer gas.

Preignition explosions can always be distinguished from ordinary explosions as they are louder and sharper.

Sometimes the fuel charge does not fire inside the engine, owing to the momentary failure of the electric spark or to a weakening of the mixture of gas and air. Suction producer gas sometimes becomes weak, particularly when the load on the engine is suddenly increased and more gas required.

In these cases the unburned fuel charge is passed out of the engine into the exhaust pipe, where it explodes with a banging noise on coming into contact with the hot gases of previous explosions. Such explosions in the exhaust pipe are called exhaust explosions or backfiring.